

pH Properties of Buffer Solutions

Inquiry Guidance and AP® Chemistry Curriculum Alignment



Introduction

The physiological role of buffers within cells and in consumer products highlights the ability of buffers to resist changes in pH. Buffers provide an essential acid-base balancing act—in foods and drugs, consumer products, lakes and streams, and even living cells. All biological cells depend on the properties of buffers, as does the essential function of the respiratory system, breathing, which must be regulated within a very narrow pH range. What are buffers made of and how do they work?

Opportunities for Inquiry

Buffers represent an integrated concept bridging many big ideas. Understanding buffers requires students to synthesize knowledge and apply reasoning skills from chemical reactions, stoichiometry, and acid-base equilibrium. The myriad applications of buffers offer many interesting opportunities to study the composition and mechanism of action of buffers.

- Promote inquiry into buffers using a colorful demonstration. Dissolve Alka-Seltzer® tablets in water, add universal indicator, and observe the color and pH changes when 1 M HCl and 1 M NaOH are added. Ask students to design similar experiments to identify the potential buffering characteristics of other consumer products, including antacids, deodorants and conditioners, mouthwashes, beverages, contact lens solution, etc.
- Acetate buffers provide a convenient introductory activity to study how the pH of a buffer depends on the relative amounts of a weak acid and its conjugate base. Extend the baseline activity by asking students to select weak acid-conjugate base combinations that will be effective at different pH values across typical physiological or aqueous chemistry. Make it a challenge! Identify the ratios and concentrations at each pH that will have the highest capacity with respect to added acid or added base. *Hint:* They are not the same!
- Challenge students to prepare a set of buffer standards for an indicator color series that can be used for narrow-range pH analysis (about 2 pH units). An example is a series of phosphate buffers containing various ratios of NaH_2PO_4 and Na_2HPO_4 solutions with bromothymol blue (pH = 6.0–7.6).
- Forensic analysis of DNA by electrophoresis requires a buffer that will keep the charge on the DNA molecules relatively constant so that their migration in an electric field will depend only on their size. Research, prepare and study the pH profiles of electrophoresis buffers.
- Most enzymes have an optimum pH value for maximum activity. How are buffer solutions used to determine the optimum pH for a common enzyme such as amylase, catalase or pectinase?

Alignment with AP Chemistry Curriculum Framework—Big Ideas 3 and 6

Enduring Understandings and Essential Knowledge

Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form. (Enduring Understanding 3A)

3A2: Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to simply be an exercise done only by chemists.

Chemical reactions can be classified by considering what the reactant are, what the product are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid-base, and oxidation-reduction reactions. (Enduring Understanding 3B)

3B2: In a neutralization reaction, protons are transferred from an acid to a base.

Chemical equilibrium plays an important role in acid-base chemistry and in solubility. (Enduring Understanding 6C)

6C1: Chemical equilibrium reasoning can be used to describe the proton transfer reactions of acid-base chemistry.

6C2: The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to pK_a allows one to determine the protonation state of a molecule with a labile proton.

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L Darling-Hammond



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